Long-term results and physiotherapeutic determination in operative treatment of intra-articular calcaneal fractures

Czynnościowe wyniki odległe oraz uwarunkowania fizjoterapeutyczne leczenia operacyjnego złamań stawowych kości piętowej

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Key words
intra-articular, calcaneal fractures, complications, physiotherapy

Abstract
Introduction: The authors present their own observations of the surgical treatment of articular calcaneal fractures using a minimally invasive percutaneous fixation in combination with the unified self-developed physiotherapy program.
Material and methods: The analyzed techniques include the Westhues' technique and its modification with additional stabilization of the bone fragments with Kirschner wires, as well as transdermal stabilization by Rąpała. The research material comprises 82 patients with intraarticular fractures - 68 men (83%) and 14 women (17%) treated surgically between 1990 and 2012. The analyzed calcaneus fractures were divided by Essex–Lopresti scale and evaluation of functional outcome at follow-up was based on the Creighton–Nebraska criteria.
Results: Men with the "tongue type" fracture treated using the Westhues' technique had good functional outcomes in 12 cases (17.6%) and acceptable in 7 cases (10.3%). Women with the "tongue type" fracture treated using the Westhues' technique had good functional outcomes in 2 cases (14.3%) and in one case, poor (7.1%).
Conclusions: After analysis of the material, the authors claim that minimally invasive techniques are not really minimally invasive, taking the observed complications into consideration in most of the patients, which lead to the poor functional outcome at long term follow-ups.

Słowa kluczowe
złamania stawowe kości piętowej, powikłania, fizjoterapia

Streszczenie
Wstęp: Autorzy pracy prezentują obserwacje własne z zakresu operacyjnego leczenia złamań stawowych kości piętowej z zastosowaniem przezskórnych zespoleń małoinwazyjnych w skojarzeniu ze zunifikowanym autorskim programem fizjoterapii.
Materiały i metody: Są nimi zespolenie Westhuesa oraz jego modyfikacja z dodatkową stabilizacją odłamów kostnych drutami Kirschnera, a także przezskórna stabilizacja sposobem Rąpały. Materiał badań obejmuje lata 1990- 2012, a stanowi go 82 operowanych, w tym 68 mężczyzn (83%) i 14 kobiet (17%). Analizowane złamania kości piętowej klasyfikowano stosując podział Essex-Lopresti, a do oceny wyników czynnościowych w obserwacji odległej posłużono się kryteriami Creighton-Nebraska.
Wyniki: Wśród mężczyzn z rozpoznanym złamaniem typu „języka", u których zastosowano zespolenie odłamów kostnych sposobem Westhuesa, wyniki dobre odnotowano u 12 operowanych, czyli u 17,6%, oraz wyniki zadowalające u pozostałych

The individual division on this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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7, czyli u 10,3%. W grupie kobiet leczonych z powodu złamań stawowych kości piętowej typu „języka" sposobem Westhuesa odnotowano wyniki dobre u 2 operowanych, czyli u 14,3%, oraz wynik zły u jednej z nich, co stanowi 7,1%.
Wnioski: Na podstawie analizy zebranego materiału autorzy pracy skłaniają się do stwierdzenia, że wymienione zespolenia odłamów kostnych są jedynie z pozoru małoinwazyjne, a powikłane zwłaszcza powikłaniami skojarzonymi u większości operowanych prowadzą w obserwacji odległej do niekorzystnych wyników czynnościowych.

INTRODUCTION

The methods of treatment of articular fractures of the calcaneus remain very controversial. The reasons for this situation can be found, among others, in the complex morphology of these fractures, often resulting in irreversible destruction of the articular surfaces, rapid development of degenerative changes sometimes accompanied by dystrophic disorders and – as a consequence – pain, with impaired gait pattern and efficiency[1-3]. This may force patients to seek frequent and prolonged physiotherapeutic support. The search for effective operational treatments of articular fractures of the calcaneus focus on a number of approaches; the approaches mainly include minimally invasive and percutaneous fixations[4-6], methods that use various types of plates[7-9] or devices for external stabilisation[10,11], or surgical procedures that use allogeneic bone grafts and hydroxyapatite substitutes to restore crushed articular surfaces[12,13]. Surgical treatment of articular fractures of the calcaneus may result in numerous complications[14-17], which puts forward the question of whether the fractures can and should be treated with non-surgical methods[18-20]. Regardless of the method of treatment of articular fractures of the calcaneus, its reasonable complement seems to be well-considered and consistently implemented physiotherapy. However, the available literature lacks comprehensive and satisfactory reports on the subject.

AIM OF THE STUDY

The aim of this study is to determine the relevance, effectiveness and scope of physiotherapy after surgical treatment of articular fractures of the calcaneus, and to answer the following questions:

1. What are the functional results in patients treated surgically after articular fractures of the calcaneus in association with the applied physiotherapy program?
2. How do complications after the surgical treatment of articular fractures of the calcaneus affect the functional results obtained?

STUDY MATERIAL

The aim of the study was formulated on the basis of the material from the Department of Trauma and Orthopaedic Surgery, 5th Military Clinical Hospital with Polyclinic in Krakow (5WSK), covering the years from 1990 to 2012. The research material was divided according to the patients' gender, age, the type of fracture sustained according to the Essex-Lopresti classification[21], the applied method of fixation of the bone fragments and the registered complications.

The study included 82 subjects treated surgically for articular fractures of the calcaneus – 68 males, comprising 83% of the group, and 14 women (17% of the group). The age of the subjects on the date of the surgery was between 34 and 67 years, averaging 48 years (34-53 years for males with an average of 41 years, and 61-67 years for women, with an average of 64 years).

Having adopted the Essex-Lopresti classification[21] in the assessment of the analyzed fractures, a tongue fracture was diagnosed in 26 men (31.7%), and depression fracture in 42 men (51.3%). As to women, a tongue fracture was diagnosed in 3 subjects (3.6%) and depression fracture in 11 subjects (accounting for 13.4%). In total, tongue fractures were identified in 29 of the patients operated on, that is in 35.3% of the subjects, and depression fractures were identified in 53 of them, that is 64.7%. The causes of the analyzed fractures were: falling from a height of less than 2 meters (19 subjects, 23.1%), falling from a height of over 2 meters (39 subjects, 47.7%), a traffic accident (16 subjects, 19.5%) and a parachute jump (8 subjects, 9.7%).

In the treatment of tongue fractures, surgery based on the fixation of the bone fragments according to the Westhues method (or, alternatively, the method with additional Kirschner wires stabilizing the bone fragments) was used. The Westhues method was applied in 19 men (23.2%), and the Westhues method with Kirschner wires in 7 of them (8.6%). In the group of men, in the surgical treatment of depression fractures, the Westhues method (with Kirschner wires) was used in 27 subjects (32.9%), and the method of percutaneous fixation of bone fragments with Kirschner wires (Rapala's method) in 15 (i.e. 18.3%). In women, the Westhues method with Kirschner wires was used to treat tongue fractures in 3 subjects (3.6%). To treat depression fractures, the same method was used in 4 subjects (4.8%); Rapala's method was used to treat the remaining seven (8.5%).

All the subjects included in the study were operated on 2 to 6 days after the fracture. The surgery was performed under local anesthesia (spinal or epidural). In patients who underwent fixation of bone fragments according to the Westhues method, the limb that was operated on was immobilized in a short-leg cast for a period of 6 to 8 weeks. During this time, thromboembolic and antibacterial prophylaxis with low molecular weight heparin preparations were being conducted, in accordance with the generally accepted principles and guidelines (Zinacef [*Cefuroximum*], Biodacyna [*Amikacinum*], Tarcefandol [*Cefamandolum*]). The Steinmann pin and Kirschner wires were removed from the calcaneus operated on in order to remove

the plaster cast. After the removal of the cast, a heel-relieving cast put applied on some of the patients, for an additional 2-week period.

The reported post-surgical complications were an important element of the conducted physiotherapeutic treatment. In men, after the surgical treatment of articular tongue fractures of the calcaneus with the use of Westhues fixation, complications in the form of deep vein thrombosis, local inflammation around the point of entry of the Steinmann pin (around the calcaneal tubercle) along with its destabilization were all noticed. Deep vein thrombosis of the lower leg was diagnosed in 2 patients operated on with this method (3%), local inflammation of the skin around the point of entry of the Steinmann pin (around the calcaneal tubercle) was found in 4 of them (5.9%), and the destabilisation of the fixation in 1 person (1.4%). In total, complications in the period of early clinical observations were noted in 7 men treated according to the Westhues method (i.e. in 10.3% of the patients treated this way). In men operated on using the Westhues method in combination with further stabilization of bone fragments with Kirschner wires, deep vein thrombosis of the lower leg was found in early observations in 3 subjects (i.e. in 4.4% of the male subjects), and local inflammation at the point of entry of the Steinmann pin was also found in 3 subjects (4.4%). A total of six cases of complications after surgical treatment of the articular fractures of the calcaneus (8.8% of the male subjects) were found during early observations in this group. During the same period of observation, in men who were treated surgically for depression fractures using the Westhues method and additional stabilization of bone fragments with the use of Kierschner wires, deep vein thrombosis of the lower leg was found in 2 patients (3%), and local inflammation of the skin at the point of entry of the fixation material in 4 of them (5.9%). Application of Rapala's method in this group of patients resulted in a deep vein thrombosis in the lower leg in 3 men (4.4%); local inflammation of the skin around the point of entry of the fixation material was found in 5 men (7.3%). In total, complications after surgical treatment for depression fractures of the calcaneus were observed in 12 subjects, i.e. 20.6% of the male group.

In total, of all the men undergoing surgery that used the above methods, complications were found during early observations in 27 persons, which is 39.7% of all men and 32.9% of the research group; venous thrombosis was found in 10 persons (14.8%), local inflammatory complications in 16 persons (23.5%) and destabilisation of fixation in 1 person (1.4%).

During the period of early clinical observation, deep vein thrombosis of the lower leg co-occurred in men with local inflammatory reactions of the skin in 7 patients (10.3%). In this group there were 4 men with depression fractures treated with the Westhues method in combination with further stabilization of the bone fragments with Kirschner wires, who accounted for 5.9% of the group; 2 men (3%) were treated for depression fractures using Rapala's method; and 1 man (1.4%) was treated for tongue fractures with the Westhues method.

In women after tongue fractures and operated on using the Westhues method in combination with a further stabilization of bone fragments with Kirschner wires, deep vein thrombosis of the lower leg was found during early observations in 2 subjects (14.3%). In women after depression fractures and also operated on using the Westhues method in combination with further stabilization of bone fragments with Kirschner wires, deep vein thrombosis of the lower leg was also found during early observations in 2 subjects (14.3%); in women treated using Rapala's method in the same group of fractures (depression), deep vein thrombosis was reported in the case of 3 persons (21.4%), and local inflammation of the skin around the point of entry of the fixation material in 4 persons, or 28.6%. Deep vein thrombosis of the lower leg co-occurred with local inflammatory reaction of the skin around the point of entry of the Kirschner wires in 6 of the women (42.8%) operated on, 4 of whom (28.6%), were treated for depression fractures with the use of the Westhues method with further stabilization of the bone fragments with Kirschner wires, and 2 of whom (14.3%), were treated for the same reasons using Rapala's method.

STUDY METHODS

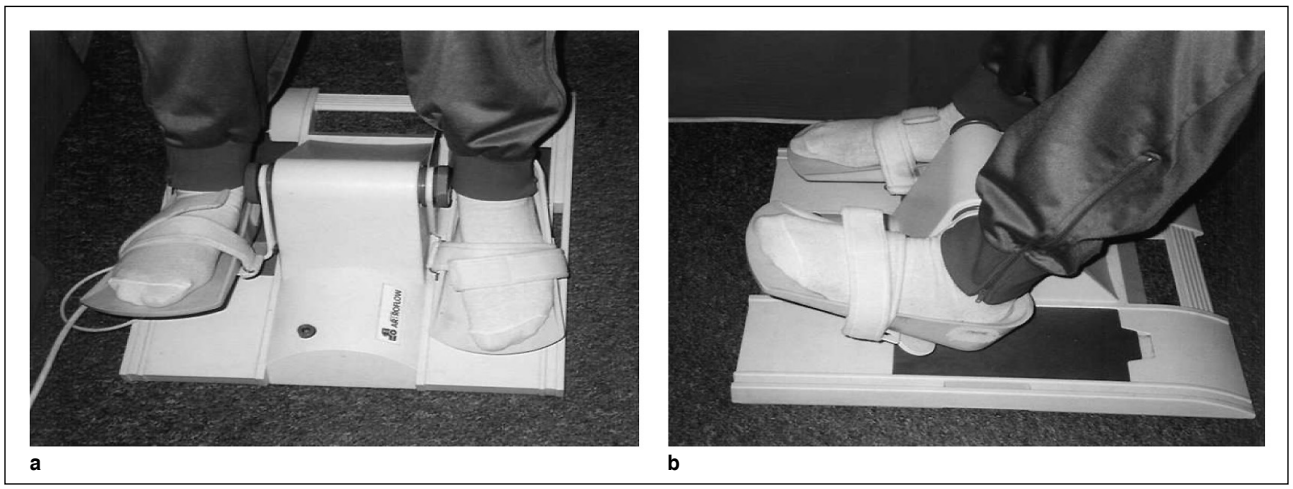
The used physiotherapeutic program was individualized according to the local and general health condition of the patients and depended on the complications registered during both early and late clinical observations.

Physiotherapeutic treatment started after a period of 1 to 2 weeks following the removal of the fixation material and was executed using a magnetic field, hydro-pneumatic massage therapy, local cryotherapy as well as passive and active exercises improving the function of foot joints. Since 1998, among others, the Artromot rail has been used to achieve this goal (the method of continuous passive motion – cf. Figure 1). Individualized anti-oedematous massage of feet and lower legs has also been used. Attempts at gradual weight bearing of the limbs operated on were taken between 10 and 12 weeks after the surgery. After this period, exercises to regain feet proprioception were also performed, with the use of various types of surfaces, as well as walking on toes and heels. The duration of the physiotherapeutic treatment was from 6 to 17 weeks, with an average of 9 weeks.

The assessment of the functional outcome, performed after a minimum of 12 months after the removal of the material fixating the fragments of the calcaneus and based on the Creighton-Nebraska scale[22], is summarized in Tables 1-2.

Methods of statistical analysis

Statistical analyses were performed using the Statistica 10 PL suite (by Statsoft). Elements of descriptive statistics (percentage distribution, mean value, standard deviation) were used to present the data. The type of data distribution was assessed using the Shapiro-Wilk Test. In the case of normal distribution of variables, the



a b

Figure 1

The Atromot device used to improve foot joints in patients after articular calcaneal fractures: a) front-view; b) side-view

Student's t-test was used to compare the groups, and the Mann-Whitney U Test in case of lack of normal distribution. The level of $p < 0.05$ was considered as statistically significant.

RESULTS

The functional results obtained in men

In the group of men who were diagnosed with tongue fractures and who underwent fixation of bone fragments using the Westhues method, 12 subjects (17.6%) showed good results, and the remaining 7 subjects (10.3%) showed satisfactory results. In men with the same type of fracture who were treated with the Westhues method combined with further stabilization of bone fragments with Kirschner wires, 4 subjects (5.9%) reported satisfactory results, and the other 3 (4.4%) reported bad results. In the case of the tongue fracture with the exception of "good" functional outcome, no other statistically significant differences in the functional effect were reported, depending on the surgical method of fixing the fracture ($p > 0.05$).

In men diagnosed with depression fractures treated using the Westhues method combined with further stabilization of bone fragments with Kirschner wires, the results were good in 14 subjects (20.6%); they were satisfactory in 7 subjects (10.3%) and bad in the remaining 6 subjects (8.8%). In men who were treated for depression fractures using Rąpala's method, that is the percutaneous fixation of bone fragments using Kirschner wires, good results were reported in 2 patients (3%), satisfactory results in 10 patients (14.7%) and bad results in the remaining 3 patients, that is 4.4%. The frequency of occurrence of the "good" results was statistically significantly higher ($p = 0.002$) among men treated with the Westhues method combined with further stabilization of bone fragments with Kirschner wires. In the case of other qualitative categories, there were no statistically significant differences between the groups independently from the method of fixing the fracture.

There were no very good results in men, regardless of the type of sustained fractures, the method of fixation of bone fragments or the registered complications. Bad results were found in 3 patients operated on using Rąpala's method due to their depression fractures; they were diagnosed with deep vein thrombosis of the lower limb co-occurring with the local inflammatory reaction of the skin around the point of entry of the Kirschner wires in the calcaneus.

The functional results obtained in women

In women treated for articular tongue fractures of the calcaneus using the Westhues method, good results were reported in 2 subjects (14.3%), and a bad result in one of them, which constitutes 7.1% of the subjects.

In women who sustained the depression fractures and who were treated with the Westhues method combined with further stabilization of bone fragments with Kirschner wires, 3 subjects (21.4%) achieved satisfactory results, and 1 subject (7.1%) achieved a bad result.

In women who underwent Rąpala's surgical treatment of articular depression fractures of the calcaneus, good results were recorded in 4 patients (28.7%); satisfactory results in 1 patient (7.1%), and bad results in the remaining 2 patients (14.3%).

No very good results were registered in women. There were, however, more bad results than in men: they were found in 4 subjects, that is in 28.7% of them. These women were also diagnosed with deep vein thrombosis of the lower limb co-occurring with the local inflammatory reaction in the entry area of the fixation material into the calcaneus.

DISCUSSION

The position on the necessity of implementing appropriate physiotherapy in the treatment of patients with articular fractures of the calcaneus seems by all means justified and appropriate. However, it is not confirmed in any comprehensive literature reports, which are missing

Table 1

Creighton-Nebraska Health Foundation assessment sheet for fractures of the calcaneus[22]	
Assessed parameters	
Experienced pain – 30 points	**Score**
During physical activity	
– no pain during walking	15
– slight degree of pain during walking	10
– pain during weight bearing	5
– pain greatly restricting physical activity	0
Physical activity – 20 points	
– unrestricted	20
– ability to walk a distance of 1 km or stand for 30 min	15
– ability to walk a distance of less than 1 km or stand for less than 30 min	10
– moves only around place of residence	5
– cannot walk	0
Range of movement – 20 points	
/ 25° – 30° = 80 – 100%	20
/ 20° – 25° = 60 – 80%	15
/ 15° – 20° = 40 – 60%	10
/ 10° – 15° = 20 – 40%	5
/ slight movement	0
Return to work – 20 points	
– full–time to previous position	20
– full–time with restrictions	15
– full–time with change of position	10
– restrictions in working time	5
– incapable of employment	0
Change in shoe size – 5 points	
– no change	5
– necessary change	0
Feet swelling	
– no swelling	5
– slight swelling	3
– moderate swelling	2
– substantial swelling	0
Total	100
km – kilometer	

Table 2

Creighton-Nebraska Health Foundation assessment sheet for fractures of the calcaneus – points and functional results[22]	
Point range	**Result**
from 90 to 100	Very good
from 80 to 89	Good
from 65 to 79	Satisfactory
< 65	Poor
< - lower	

or not particularly convincing[19,23], especially with regard to surgical patients with various kinds of complications[14-17,24] diagnosed both perioperatively and during early and distant clinical observation. Although elements of physiotherapy, as well as preventive motor behaviors against thromboembolic complications meet in the method of functional treatment of articular fractures of the calcaneus[19], it must be remembered that

the method is mainly used in patients with depression fractures with total loss of the congruence of the articular surfaces of the subtalar joint and talocalcaneonavicular articulation, or in patients in whom there exist absolute contraindications to any surgical intervention due to heavy local and systemic overloads.

The analysis of the material gathered by the authors of the present study clearly shows that the complications observed in the early and distant postoperative period result in worse functional results in some of the patients. This primarily occurs in patients who experienced associated complications, namely deep vein thrombosis of the limb with a local inflammatory reaction of the calcaneal skin in the point of entry of the fixation material into the bone. This also confirms the validity of the thesis about the importance of local inflammatory reactions in provoking thromboembolic complications. The authors of the present study also believe that poor functional results of treatment of patients with fractures of the calcaneus analyzed along the Creighton-Nebraska criteria[22] result from algodystrofic disorders recognized during the distant observation – disorders that can be an expression of involutional demineralization of bone tissue occurring in the postmenopausal period, unreasonably prolonged immobilization of the limb in a cast and individual tendency towards these types of changes. The confirmation of such a position can be found, it seems, in the results of the present study, which recorded more bad functional results in women than in men.

The unsettling conclusion of the present study is certainly the fact that the analyzed material and the fixed time period did not bring records of very good results in the adopted criteria [22], despite the use of a unified physiotherapeutic program in all the surgical patients during an average period of 8 weeks, and despite the use of minimally invasive percutaneous fixation to stabilize the bone fragments. In this context, it would seem that the use of minimally invasive percutaneous fixations in the surgical treatment of fractures of the articular calcaneus (less traumatic to the soft tissue and initially damaged bone tissue) will result in far better functional results in distant clinical observation. The cause of lack of good results is to be sought primarily in the morphology of the fracture itself and the excessive number of Kirschner wires or Steinmann tips introduced to the fracture. This seemingly minimally invasive fixation of bone fragments impairs blood flow in the fracture area, thus weakening the revascularization process, triggering demineralization of bone tissue that, in association with thromboembolic and inflammatory complications, result in a negative functional outcome.

In the early postoperative period, the introduction of initially passive and then active movement in the ankle and other joints of the foot operated on, simultaneously triggering the values of muscle pump in restoring normal blood flow in this area is, according to the authors of the present study, one of the conditions for successful treatment of severe damage to the calcaneus[2,19]. This procedure is also believed to condition the effectiveness of thromboembolic complication prevention. The authors of the present study also believe that the combination of the Westhues method with additional stabilization of bone fragments with the use of Kirschner wires, and above all the additional limb immobilization in a cast is – for all the above reasons – unconvincing and unreasonable. The Westhues method is and should be used only in patients with tongue fracture type[23].

CONCLUSIONS

1. Surgical treatment of articular fractures of the calcaneus using percutaneous fixation in combination with the unified program of physiotherapy, based on the accepted Creighton-Nebraska criteria, in the majority of surgical patients results in good and satisfactory results during distant clinical observation.
2. Complications after surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation, and especially the nature of the associated inflammatory and thromboembolic complications lead to adverse final results (based on the assumed functional Creighton-Nebraska criteria).

Conflict of interest: none

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